CHAPTER 4.0: WATER QUALITY

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Prepared by:

Joy Michaud

GLOSSARY

BOD: Biochemical Oxygen Demand

CFS: Abbreviation for cubic feet per second, a measurement of streamflow volume.

Discharge: Outflow; the flow of a stream, canal, or aquifer.

Disturbance: Events that can affect watersheds or stream channels, such as floods, fires, or landslides. They may vary in severity from small-scale to catastrophic, and can affect entire watersheds or only local areas.

DO: Dissolved Oxygen

Ecology: Washington Department of Ecology

EPA: Environmental Protection Agency

Gaging station: A selected section of a stream channel equipped with a gage, recorder, or other facilities for measuring stream discharge.

GWMA: Ground Water Management Area

Infiltration: The rate of movement of water from the atmosphere into the soil.

Large Woody Debris (LWD) recruitment: The amount or size of large trees in a riparian area that could potentially fall in (recruit) to the stream channel. Mechanisms for recruitment include small landslides, bank undercutting, windthrow during storms, individual trees dying of age or disease, and transport from upstream reaches.

Large Woody Debris (LWD): Logs, stumps or root wads in the stream channel, or nearby. These function to create pools and cover for fish, and to trap and sort stream gravels.

NMFS: National Marine Fisheries Service

RM: River Mile

Salt Wedge: The intrusion of salt water into the lower reaches of a stream during high tide. Since fresh water floats on salt water, this intrusion is often wedge shaped, hence the name.

Substrate: Mineral or organic material that forms the bed of a stream.

TES: Threatened or endangered species.

Tidal Influence (on streams): Tides often influence the flow in the lower reaches of streams draining to salt water. The influence includes both the intrusion of the salt wedge and the backup of freshwater above the salt wedge, which is caused by the increase in the height of water during high tide. Hence, the tidal influence can extend a substantial distance above the salt wedge.

TMDL: Total Maximum Daily Load

TSS: Total Suspended Solids

USFWS: United States Department of Fish and Wildlife Services

USGS: United States Geological Survey

Watershed: an area of land that drains down slope to the lowest point. Drainage pathways may converge into a stream or river, or may end in a marsh or ancient lakebed.

WDFW: Washington State Department of Fish and Wildlife

WDNR: Washington State Department of Natural Resources

WDOE: Washington State Department of Ecology

WDOH: Washington State Department of Health

WRIA: Water Resources Inventory Area

CHAPTER 4.0: WATER QUALITY

INTRODUCTION

The following Surface Water Quality Assessment for the lower Nisqually River basin was developed to meet the needs for a Level 1 Assessment under the Watershed Management Act of 1998. Existing information and investigative studies performed by the Nisqually Indian Tribe have been largely relied upon in developing the assessment. The condition of each subbasin and the Nisqually lower mainstem is described in terms of whether it meets water quality standards for dissolved oxygen, temperature, and fecal coliform bacteria. These parameters were selected for the assessment because of their direct relationship with fisheries and water quantity issues, which are the driving forces for this watershed planning effort. Where water quality standards violations have resulted in listing the water body in the 303(d) list of impaired waters, this has been identified in addition to describing whether there are “Clean Up Plans” or “TMDLs” planned for the subbasin.

SURFACE WATER QUALITY

METHODS AND APPROACH

The Nisqually Indian Tribe maintains a water quality database for the river. This database consists of data collected during different water quality investigations of the river and its tributaries and from Washington Department of Ecology’s (Ecology) ambient monitoring program. This means that the period of record, frequency of sampling, and number of data points is highly variable between stations and subbasins. In order to adequately utilize this data set, yet allow for comparisons of similar data groupings, a subset of this data was used. Data tables were created for each subbasin for two different seasons of interest. Data from the months of July through September have been summarized to represent worse case summer period conditions. Data from the months of November through March have been summarized to represent worse case winter period conditions. (The month of September was included with the summer period because in a number of the subbasins flows are lowest during September.)

All data for a selected station that fell within these date ranges was used to create a table showing the minimum, maximum, and average concentrations measured at the station. (Note: Geometric mean values were calculated for bacteria concentrations as well as percent exceedance calculations to allow for direct comparison to water quality standards.) In order to make up- and downstream comparisons, two stations were selected for most of the subbasins. However, this means that for some of the stations summarized, the data record is sparse.

In addition to summarizing the data found in the database in terms of water quality standards, a summary of report findings from a number of extensive water quality investigations performed by the Nisqually Indian Tribe is also included.

Although the data tables created contain a summary of nutrients, TSS, and turbidity, only dissolved oxygen, temperature, and fecal coliform bacteria results are described in this text. These parameters were selected because of their direct relationship with fisheries and water quantity issues and therefore the purpose of this Level 1 Assessment.

WATER QUALITY CRITERIA

Water quality standards have been set for surface waters of Washington State that are based on the beneficial uses of the water. These standards are described in WAC 173-201A. The Nisqually River above RM 44.2 (Alder dam) has been defined as a Class AA (extraordinary) water, while the river below RM 44.2 has been as Class A (excellent) waters. Since this Level 1 assessment is focused on the river below RM 39, the Class A standards apply (Table 4-1).

On a biennial basis, the EPA is required, through Section 303(d) of the Clean Water Act, to create a list of "impaired" waterways in the U.S. Although there are numerous ways that a waterbody can be justified for inclusion in this list, the most frequently used method for Washington State waters is an assessment of whether State water quality criteria are being met. If criteria are not met, the waterbody will be added to the list. Once a stream is listed as impaired, it becomes the State's responsibility to develop or support a plan for handling the problem. One tool used for developing strategies to improve water quality is a Total Maximum Daily Load (TMDL) study. In this assessment 303(d) listed segments are summarized and TMDLs noted.

Table 4-1. Selected Washington State Water Quality Criteria for Class A Waters.

Class	Temperature	DO	Fecal Coliform
A	Shall not exceed 18°C from human conditions or if >18°C exists naturally, no temp increase >0.3°C	Shall exceed 8.0 mg/L	Shall not exceed a geometric mean of 100 colonies/100mL and shall not have > 10% of all samples exceeding 200 colonies/100mL

In terms of dissolved oxygen and temperature, the critical time period is typically mid to late summer when solar influx is high and flows are low. There is less physical turbulence and mixing to add oxygen, and primary productivity is higher which decreases oxygen. Simultaneously, the low flows and high air temperatures equate to a smaller volume of water receiving more heat, and therefore higher stream temperatures. The combination of low dissolved oxygen concentrations and high temperatures can represent a critical situation for salmon and other aquatic species. Conversely, the winter high flow season equates to higher water volumes and cooler water temperatures, but increased surface runoff can result in high concentrations of suspended particles and associated pollutants, such as fecal coliform bacteria, total suspended solids, and nutrients. Fecal coliform bacteria levels may be high in either season depending upon how the source is generated.

In the following analysis of water quality, two subsets of the yearly data have been created to evaluate these critical case conditions for the 6 subbasins and the Nisqually Mainstem. Data from July through September was used to represent the period of high temperature and low flows, while data from November through March was used to represent the wet weather period. The intent of this analysis is to summarize the condition of each subbasin but not to make specific determinations of standards violations. The standards are used as bench marks for comparison purposes.

WATER QUALITY CONDITION AND POLLUTANT SOURCES

McAllister Subbasin

McAllister Creek is over 6 miles long and drains an area of 39.2 square miles. A number of springs comprise its headwaters, the largest have been developed by the City of Olympia to provide urban water supply. McAllister Creek also receives flow from a number of smaller springs located along the west border of the lower Nisqually valley and receives flow from Medicine Creek and Little McAllister Creek. McAllister Creek is primarily bordered by agricultural land, and the lower portion of the stream is within or bordering the Nisqually National Wildlife Refuge. The stream is subject to tidal influence up to RM 5.5, which is most of the stream. Its lower 2.5 miles is estuarine. The majority of the subbasin drains directly to the Puget Sound however a small portion (11.1 square miles) drains to the lower Nisqually mainstem. Average annual discharge of the subbasin was calculated as 86.5 cfs. This calculation was based on a calculation of average annual flows reported by AGI Technologies (1999) for McAllister “proper”. Flows for the remaining portion of the subbasin (i.e. the portion draining to the Nisqually) were calculated by assuming the same unit runoff (see Chapter 5.1 for further discussion).

Table 4-2 contains a summary of water quality data from an upper (RM 6.3) and lower (RM 3.1) station within the McAllister subbasin. At the upper station monthly samples were collected from 1993-1995, at the lower station monthly samples were collected in 1994, 1995, and 1997. The data is summarized from a database provided by the Nisqually Indian Tribe.

As is shown in the table, the mean dissolved oxygen concentrations at both the upper (RM 6.3) and lower (RM 3.1) stations meet the criteria during the summer months. However, as indicated by the minimum levels, there are violations of the state standard. Annually, 23% of the dissolved oxygen measurements at RM 3.1 and 57% of the measurements at RM 6.3 are below the state standard for dissolved oxygen. In a data set provided by Thurston County Environmental Health (Davis, S. Pers. Comm.), 41% of the samples did not meet the standard. Interestingly, dissolved oxygen levels are low in this stream even during winter months. The specific cause or source of this problem has not been clearly identified. Flushing problems and surface runoff have been implicated, however water at the upper site is entirely of a groundwater source, which normally has low dissolved oxygen levels. Hence, low dissolved oxygen levels at this site are likely natural. Further downstream, low dissolved oxygen is likely influenced by both the influence of groundwater sources and the presence of peat, which uses available dissolved oxygen as it decays. Runoff of organic materials and fertilizers may also contribute to the problem.

All temperature measurements have met the standard. This is likely a reflection of the groundwater influence on the stream, since groundwater remains cool year-round.

Table 4-2. McAllister Subbasin, Water Quality Summary. (Data Source: Nisqually Indian Tribe Water Quality Program database.)

Parameter/Location	Summer Range (1)					Winter Range (2)				
	min	max	mean (3)	% exceedance	N	min	max	mean (3)	% exceedance	N
DO (mg/L)										
McAllister-RM 3.1	6.8	9.2	8.2	44%	9	7.4	11	9	22%	18
McAllister-RM 6.3	6.3	10	8	57%	7	6	10.6	7.8	57%	7
Temp (C)										
McAllister-RM 3.1	11.7	17.1	14.3	0%	9	5.6	11.1	8.9	0%	17
McAllister-RM 6.3	11	14.6	12.2	0%	7	9.4	10.8	10.1	0%	7
Fecal Coliform (MPN/100ml)										
McAllister-RM 3.1	35	470	85.1	11%	9	50	460	107.9	18%	17
McAllister-RM 6.3	4	5	4.7	0%	4	5	105	23	0%	6
Turbidity (NTU)										
McAllister-RM 3.1	0.9	3.5	2.5		9	2.2	11.3	5.9		22
McAllister-RM 6.3	0.3	4.1	1.2		7	0.1	1.2	0.8		8
TSS (mg/L)										
McAllister-RM 3.1	0.5	2.4	1.6		9	2.6	13.6	8.5		17
McAllister-RM 6.3	0.5	9.5	2.5		6	0.5	1	0.6		9
TP (ug/L)										
McAllister-RM 3.1	108	149	129.2		3	127	184	157		6
McAllister-RM 6.3	89	127	106		3	102	118	110		6
NH_3 (ug/L)										
McAllister-RM 3.1	53	62	57.2		3	79	145	118		6
McAllister-RM 6.3	23	45	34.7		3	10	38	24.2		6
Nitrate (ug/L)										
McAllister-RM 3.1	1000	1050	1019.8		3	1100	2000	1415		6
McAllister-RM 6.3	838	1010	946		3	1240	1540	1323		6

(1) Summer range calculated using July - September data.
(2) Winter range calculated using November - March data.
(3) Arithmetic mean calculated for all parameters, with the exception of Fecal Coliform which was calculated as the geometric mean value.

At RM 3.1, the bacteria standard is exceeded during both summer and winter data sets. Although the geometric mean values are low or just above the criteria, the percent of samples exceeding the 200 limit is greater than 10% (i.e. 11 to 18%). Using this data subset, at the upper station, bacteria standards are met. Investigative studies of fecal coliform sources to the Nisqually (Whiley & Walter, 1998) and into Nisqually Reach (Whiley & Walter, 1996) both identified McAllister Creek as a primary source. It was concluded that fecal coliform concentrations were chronically elevated and positively correlated to rainfall and associated stormwater runoff (Whiley & Walter, 1996). A significant correlation was also found between fecal coliform concentrations measured in McAllister Creek and those measured over the shellfish beds located in Nisqually Reach (Whiley & Walter, 1998). Typically, elevated fecal coliform levels are the result of runoff of animal waste and/or leaky septic tanks.

Ecology is currently doing a source tracking study in McAllister Creek. They are collecting fecal coliform and enterococci samples at two-week intervals from numerous places in the system. Initial measurements have resulted in some extremely high values (e.g. 22,000 and 110,000 organisms per 100mL) at the tide gates (Dickes, B. Pers. Comm.). The results from this study will not be available until the end of year at the earliest.

McAllister Creek is included on EPA's 303(d) list due to both dissolved oxygen and fecal coliform problems. A TMDL is recommended, but has not begun. This TMDL effort is listed on Ecology's priority list for FY2002. It is likely that the project will be approved and TMDL efforts will begin within the next year (Anderson, D. Per. Comm.).

Muck/Murray Subbasin

Muck Creek

The following description of the Muck Creek subbasin was largely excerpted from a previous report (Whiley et al., 1994). The Muck Creek basin comprises an area of 92 square miles in southeastern Pierce County. The creek is confluent with the Nisqually River at RM 10.6. In its upper portions, Muck Creek has a rolling topography with underlying soils of impermeable glacial till. In the lower reaches, the soils are more permeable glacial outwash and the topography is nearly level.

The flow is intermittent from RM 0.5 to 4.0 and from RM 9 to 14. Flows increase following sustained rain and increase in water table elevation. In the lower reaches there are a few short spring-fed tributary streams, most notably Exeter Springs located at RM 2.5. These groundwater sources comprise the majority of the yearly flow in lower Muck Creek. At times, flow in the lower reaches is also supplemented by discharge from a series of lakes and wetlands present between RM 6.3 and 8.8. The largest of these lakes, Chambers Lake, is maintained by a small dam at RM 6.9. Muck and Murray Creek combined, have an average annual discharge of 132.4 cfs and contribute approximately 7% of the average annual flow to the Nisqually. (Average annual discharge was calculated using stream flow data from representative USGS stream gages and adjusting these values to the area of the subbasin. Please refer to Chapter 5.1 for a discussion of which gages were used to represent each subbasin.)

As of the 1994 report (Whiley et al., 1994), land use was approximately 70% open prairie and forestland, 10% agriculture, and 20% low density residential. Most of the lower 14 miles of Muck Creek lie within the Fort Lewis Military Reservation. Residential development is rapidly increasing with this subbasin.

Table 4-3 contains a summary of water quality data from an upper (RM 6.3) and lower (RM 0.5) station within Muck Creek, and upper (Highway 507 crossing south of Roy) and lower (mouth) station within Murray Creek. At the upper Muck Creek station, samples were collected monthly in 1991 and 1996-1998. At the lower station, samples were collected monthly in 1991 and 1999 and in various intensive studies in 1995, 1996 and 1997. The data was summarized from a database provided by the Nisqually Indian Tribe.

According to the hydrologic analysis, both of the Muck Creek stations are within the lower basin and lie within the zone of perennial flow. However, it can be assumed that the flow at the upper station would be seasonally very low, and may sometimes be indicative of lake and wetland water quality rather than typical stream quality.

Table 4-3. Muck/Murray Subbasin, Water Quality. (Data Source: Nisqually Indian Tribe Water Quality Program database.)

Parameter/Location	Summer Range (1)					Winter Range (2)				
	min	max	mean (3)	% exceedance	N	min	max	mean (3)	% exceedance	N
DO (mg/L)										
Muck-RM 0.5	9.1	13.2	11.3	0%	21	9.4	13.9	11.8	0%	33
Muck-RM 6.3	6.9	9	8.1	30%	10	7.5	11.9	9.7	6%	18
Murray-lower	7.6	8.8	8.2	33%	6	8.4	11.5	10.5	0%	7
Murray-upper	6.2	8.4	7.4	25%	4	7.2	10.1	8.8	20%	10
Temp (C)										
Muck-RM 0.5	10.5	14.3	12.5	0%	27	4.4	11.1	8.3	0%	35
Muck-RM 6.3	14.6	28.7	19.8	58%	12	4.5	11	8.1	0%	22
Murray-lower	13.3	19.9	15.6	14%	7	6.8	10.8	8.4	0%	9
Murray-upper	14.2	16.8	15.9	0%	4	4.3	9.8	7	0%	12
Fecal Coliform (MPN/100ml)										
Muck-RM 0.5	5	130	19	0%	12	5	440	13.6	7%	14
Muck-RM 6.3	130	430	243.5	50%	4	14	4775	118.4	25%	4
Murray-lower	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Murray-upper	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Turbidity (NTU)										
Muck-RM 0.5	0.1	2.5	1		22	0.1	7	1.9		39
Muck-RM 6.3	0.8	2.6	1.4		10	0.2	5	1.7		19
Murray-lower	1.3	2.2	1.8		5	0.7	5.6	3		7
Murray-upper	1.7	2.2	1.9		4	0.8	5.4	3.5		10
TSS (mg/L)										
Muck-RM 0.5	0	1	0.4		20	0	60.3	5		33
Muck-RM 6.3	0	3.8	1.1		9	0.2	4	1.7		18
Murray-lower	0.7	1.9	1.3		5	0	4.6	2		8
Murray-upper	0.6	3.2	1.8		4	0	6.1	2.5		11
TP (ug/L)										
Muck-RM 0.5	6	20	13.6		11	17	83	35		12
Muck-RM 6.3	77	118	94.5		4	50	264	151		3
Murray-lower	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Murray-upper	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
NH_3 (ug/L)										
Muck-RM 0.5	12	57	28.6		5	18	48	33		2
Muck-RM 6.3	32	60	40.5		4	19	2290	777		3
Murray-lower	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Murray-upper	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Nitrate (ug/L)										
Muck-RM 0.5	379	636	511.4		11	477	1030	782.9		12
Muck-RM 6.3	19	30	25		4	522	1120	829		3
Murray-lower	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Murray-upper	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a

(1) Summer range calculated using July - September data.
(2) Winter range calculated using November - March data.
(3) Arithmetic mean calculated for all parameters, with the exception of Fecal Coliform which was calculated as the geometric mean value.

The upper station is located just downstream of the series of lakes and wetlands previously described. During summer low flow conditions, mean dissolved oxygen concentrations just meet the standard at this upper station, thus there are occasions when it is not met. Mean temperature at the upper station is also problematic during low flow, and does not meet criteria. Temperatures exceed the normal lethal range for all salmonids. These conditions are likely a natural function of the very low flows that occur at this upper site and the strong influence from lake and wetland discharge. Temperatures at the lowest station (RM 0.5) are some of the lowest in the subbasins to the Nisqually (Whiley et al., 1994). The difference between these stations is an example of the difference between water quality characteristics of standing surface water and groundwater. This difference is also supported by the fact that Muck Creek has low turbidity levels; second lowest of the lower Nisqually subbasins. Again, this was attributed to the influence of groundwater discharge (Whiley et al., 1994).

Fecal coliform bacteria standards are not met at the upper station on Muck Creek; both parts of the standard are exceeded during both summer and winter periods. According to previous studies (Whiley et al., 1994), the high concentrations at the upper station are likely due to the agricultural land use in this part of the basin.

As concluded by Whiley et al., (1994), Muck Creek is the least impacted by nonpoint source pollution of all the study streams. Only nitrate was detected at elevated levels and this was attributed to the influence of groundwater as is described later in this chapter.

Murray Creek

Murray Creek is a small subbasin, approximately one-fourth the size of Muck Creek, that discharges directly to the Nisqually near RM 19.1. It drains entirely lowland area. Murray Creek has not been extensively studied or described in previous reports. For this report, the Nisqually Tribe database was summarized, which provided monthly samples collected from 1996-1998.

As indicated by results in Table 4-3, mean summer period dissolved oxygen concentrations do not meet standards at the upper station, and are even occasionally below the standard during the winter months at this station. Minimum standards are violated at times at both stations in summer, but the minimum measured value is above the normal lethal level. Temperatures periodically exceed the standard at the lower station during the summer. Maximum temperatures are within the range that does not normally cause mortality, but may have other sublethal effects in fish. No fecal coliform bacteria data were available.

Yelm Subbasin

The Yelm subbasin drains 52 square miles of prairie around the city of Yelm. The average annual discharge is 40 cfs. (Average annual discharge was calculated using stream flow data from representative USGS stream gages and adjusting these values to the area of the subbasin. Please refer to Chapter 5.1 for a discussion of which gages were used to represent each subbasin.) Yelm Creek contributes approximately 2% to the annual flow to the Nisqually River. The headwaters arise from wetlands and springs that have developed in the depressions of the deep, poorly drained soils. The lower portion lies on permeable glacial outwash terraces, where numerous springs provide the majority of the yearly flow. The stream discharges directly to the Nisqually at RM 13.1.

Yelm Creek is intermittent above RM 1.4. At RM 0.2, where the stream is perennial, there is relatively little variation in flow between the wet and dry seasons. Stream flows show little seasonal variation, which indicates that groundwater is an important contributing source, and that the stream is not greatly influenced by surface runoff. This, and other evidence that will be described below, supports the fact that groundwater is the most important contributor to flow and therefore greatly influences water quality in this subbasin.

Only one station on Yelm Creek has been consistently monitored, with monthly samples in 1991, 1992, and 1997-1999, an intensive yearlong study in 1995, and an intensive summer study in 1996. The data were summarized from a database provided by the Nisqually Indian Tribe.

Neither dissolved oxygen nor temperature appears to be problems in Yelm Creek (Table 4-4). Given the small size of the stream and its lowland location this is somewhat unusual, and is an indication of the influence of cooler groundwater as the major contributor to flow. (It should be noted that nitrate concentrations are very high (i.e. greater than 500 ug/L) in Yelm Creek (Whiley et al., 1994); providing further evidence of groundwater contribution as well as providing evidence of groundwater contamination.)

Table 4-4. Yelm Subbasin, Water Quality Summary. (Data Source: Nisqually Indian Tribe Water Quality database.)

Parameter/Location	Summer Range [1]					Winter Range [2]				
	min	max	mean [3]	% exceedance	N	min	max	mean [3]	% exceedance	N
DO (mg/L)										
Yelm-RM 0.2	9.4	12.8	11	0%	15	8.8	13.5	11.4	0%	29
Temp (C)										
Yelm-RM 0.2	10.5	14.1	12.4	0%	23	5	11.7	8.7	0%	33
Fecal Coliform (MPN/100ml)										
Yelm-RM 0.2	15	345	67.8	15%	13	5	4000	51.8	18%	16
Turbidity (NTU)										
Yelm-RM 0.2	0.5	2.7	1.5		20	0.3	19.6	3		32
TSS (mg/L)										
Yelm-RM 0.2	0	3.9	0.8		18	0	44.6	5.6		28
TP (ug/L)										
Yelm-RM 0.2	12	30	19.8		11	12	357	76.5		15
NH_3 (ug/L)										
Yelm-RM 0.2	10	130	60.4		5	25	27	26		2
Nitrate (ug/L)										
Yelm-RM 0.2	1040	3280	2204		10	767	2820	1704.8		15

(1) Summer range calculated using July - September data.
(2) Winter range calculated using November - March data.
(3) Arithmetic mean calculated for all parameters, with the exception of Fecal Coliform which was calculated as the geometric mean value.

The fecal coliform bacteria standard is exceeded during both the summer and winter critical periods, with 15-18% of the samples exceeding the upper limit of 200. Non-commercial farms and a beef cattle operation in the lower reaches of this stream have been suggested as possible problem sources (Whiley et al., 1994). This is supported by the elevated ammonia concentrations measured in the stream (Whiley et al., 1994). Yelm Creek is not included in the 303(d) list at this time.

Toboton/Powell/Lackamas Subbasin

These three streams are small tributaries to the Nisqually that together drain an area approximately 27.8 square miles. They are all short and each flows directly to the Nisqually between RM 28.8 and 31.9. The subbasin is characterized by a number of lakes including Clear (Thurston County), Elbow, and Bald Hills Lakes. Toboton and Lackamus do not appear to be directly affected by lakes (i.e. no direct source). However, Powell may be seasonally affected by discharge from Elbow Lake and there is a notable ponded wetland system within the lower reach. The three tributaries have a combined annual discharge of 53.6 cfs and contribute approximately 3% of the annual flow to the

Nisqually. (Average annual discharge was calculated using stream flow data from representative USGS stream gages and adjusting these values to the area of the subbasin. Please refer to Chapter 5.1 for a discussion of which gages were used to represent each subbasin.)

There is little water quality data available for these streams. Water quality data was collected from RM 0.5 and RM 0.9 on the Toboton and Powell, respectively. Data was also collected from one station on the Lackamas. The Toboton station was monitored during an intensive winter study in 1995 and on a fairly routine basis for 1996-1999. Lackamas and Powell Creek were monitored on a routine basis from 1995-1998. Table 4-5 contains a summary this data, summarized from the Nisqually Tribe database.

Dissolved oxygen concentrations are clearly a problem on Powell Creek during the summer and even occasionally during the winter. The mean summer concentration is well below the water quality standard. The stream temperature criterion is also exceeded occasionally in Powell Creek. This and the lower dissolved oxygen concentrations in this stream are likely a natural reflection of the ponded wetland that provides the major water source. The combination of low summer dissolved oxygen levels and high stream temperature may have adverse effects on fish populations.

The minimum dissolved oxygen concentration in Lackamas was somewhat lower than the standard, but, on average, this stream appears to just meet dissolved oxygen criteria. Stream temperature is also good.

Toboton Creek meets the dissolved oxygen and temperature criteria.

No fecal coliform data are available for these streams.

Table 4-5. Toboton/Powell/Lackamas Subbasin, Water Quality Summary. (Data Source: Nisqually Indian Tribe Water Quality Program database.)

Parameter/Location	Summer Range (1)					Winter Range (2)				
	min	max	mean (3)	% exceedance	N	min	max	mean (3)	% exceedance	N
DO (mg/L)										
Toboton-RM 0.5	8.2	8.9	8.5	0%	4	8.6	12.3	11	0%	12
Powell-RM 0.9	5.3	6.5	5.9	100%	4	6.1	11.8	9.1	18%	11
Lackamas	7.3	8.8	8	50%	4	8.5	12.8	11.3	0%	12
Temp (C)										
Toboton-RM 0.5	11	14	12.5	0%	8	6.1	10.8	7.9	0%	17
Powell-RM 0.9	14.9	21	17.6	40%	5	4.2	10.5	7.2	0%	16
Lackamas	12.5	16.5	14.9	0%	7	5.6	11	7.5	0%	16
Fecal Coliform (MPN/100ml)										
Toboton-RM 0.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Powell-RM 0.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Lackamas	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Turbidity (NTU)										
Toboton-RM 0.5	1	1.6	1.2		5	1.3	6.4	3.7		11
Powell-RM 0.9	1.3	2.2	1.8		4	4.6	8.6	6.5		10
Lackamas	1.5	2.2	1.9		4	3.7	10.8	5.8		11
TSS (mg/L)										
Toboton-RM 0.5	0	2.6	1.5		5	0.4	8.5	3.9		13
Powell-RM 0.9	0.3	1.5	1.1		4	0	6.5	2.3		12
Lackamas	0.1	2.8	1.4		4	0.3	4.5	1.9		13
TP (ug/L)										
Toboton-RM 0.5	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Powell-RM 0.9	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Lackamas	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
NH_3 (ug/L)										
Toboton-RM 0.5	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Powell-RM 0.9	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Lackamas	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Nitrate (ug/L)										
Toboton-RM 0.5	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Powell-RM 0.9	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Lackamas	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a

(1) Summer range calculated using July - September data.
(2) Winter range calculated using November - March data.
(3) Arithmetic mean calculated for all parameters, with the exception of Fecal Coliform which was calculated as the geometric mean value.

Tanwax/Kreger/Ohop Subbasin

Similar to the above subbasin, these three streams are tributaries to the Nisqually. Together they drain an area approximately 82.1 square miles, with an average annual discharge of 158.2 cfs. (Average annual discharge was calculated using stream flow data from representative USGS stream gages and adjusting these values to the area of the subbasin. Please refer to Chapter 5.1 for a discussion of which gages were used to represent each subbasin.) This subbasin contributes approximately 9% of the average annual flow to the Nisqually. It is also characterized by a number of lakes. In this case, all three streams are directly influenced by one or more lakes; most notably Tanwax Lake (Tanwax Subbasin), Kreger and Silver Lakes (Kreger subbasin) and Ohop Lake (Ohop subbasin).

Tanwax Creek

The Tanwax drains approximately 27 square miles and is confluent to the Nisqually at RM 30.8. It is greatly influenced by lakes and wetlands. A series of lakes form the headwaters, the largest being Tanwax Lake at RM 11.3. There are 10 other lakes and numerous wetlands throughout its 13 mile length (Whiley et al., 1994). Stream flows are closely related to lake discharge, the result is a large variation in stream flows. Land use is somewhat opposite of what is found in other subbasins in the Nisqually. In this case, the forested area is located in the lower reach of the subbasin. Agricultural land use dominates within the middle reach, while non-rural recreational and residential homes occur within the upper reach along the lakes.

Table 4-6 is a summary of the Nisqually Indian Tribes database for the selected seasonal periods. At RM 10.5, below the influence of Tanwax Lake, limited data was collected (17 samples between 1991 and 1997). A more extensive record is available for RM 0.5 in the lower subbasin between 1995-1999, including a year-long intensive study in 1995 and an intensive winter study in 1996.

Table 4-6. Tanwax/Kreger/Ohop Subbasin, Water Quality Summary. (Data Source: Nisqually Indian Tribe Water Quality Program database.)

Parameter/Location	Summer Range (1)					Winter Range (2)				
	min	max	mean (3)	% exceedance	N	min	max	mean (3)	% exceedance	N
DO (mg/L)										
Tanwax-RM 0.5	8.7	11.2	10	0%	18	6.7	13.4	11.2	4%	24
Tanwax-RM 10.5	4.3	4.3	4.3	100%	1	6.8	10.2	8.9	20%	5
Ohop-RM 0.2	6.3	10	8.1	50%	16	8.6	13.6	11.3	0%	25
Ohop-RM 6	3.2	10	7	57%	28	6.8	14.4	10.3	10%	30
Ohop-RM 9.9	8.3	11.2	9.9	0%	24	9.6	15	12.3	0%	21
Temp (C)										
Tanwax-RM 0.5	12.6	21.2	16.5	39%	23	1.4	10.6	6.5	0%	27
Tanwax-RM 10.5	13.7	16.8	14.8	0%	3	5.1	12.1	8.1	0%	6
Ohop-RM 0.2	10.9	21.4	15.7	16%	19	1.1	11	6.1	0%	28
Ohop-RM 6	11.7	27.1	20.1	65%	34	3.9	12.2	7.3	0%	34
Ohop-RM 9.9	8.7	19.4	14.5	8%	25	3.3	9.1	6.2	0%	23
Fecal Coliform (MPN/100ml)										
Tanwax-RM 0.5	5	125	21.3	0%	7	5	320	44.6	8%	12
Tanwax-RM 10.5	10	130	47	0%	9	5	70	18.7	0%	4
Ohop-RM 0.2	25	6510	300	53%	19	10	1680	77.2	22%	27
Ohop-RM 6	8	3700	66.9	15%	13	5	160	12.2	0%	21
Ohop-RM 9.9	15	660	94.3	24%	4	5	80	13.7	0%	12
Turbidity (NTU)										
Tanwax-RM 0.5	1	3.3	2		19	0.9	63	6.3		42
Tanwax-RM 10.5	4.1	5.1	4.6		2	1.9	4.6	3.1		6
Ohop-RM 0.2	1.5	10.6	6.6		16	3.4	248	17.6		43
Ohop-RM 6	1	7.1	3.1		24	1.3	63.2	9.2		54
Ohop-RM 9.9	2	16.8	5.4		17	2.5	468.6	19.6		39
TSS (mg/L)										
Tanwax-RM 0.5	0	2.1	0.7		15	0.3	67.7	5		39
Tanwax-RM 10.5	1	31	15		3	1.9	6.5	3.3		4
Ohop-RM 0.2	1.6	9.3	4.7		15	1.1	168.5	16		39
Ohop-RM 6	0.5	12.1	2.5		22	0.5	47.1	5		53
Ohop-RM 9.9	0.5	19.1	3.3		14	0.5	2037.6	65.4		38
TP (ug/L)										
Tanwax-RM 0.5	25	37	32.2		6	29	158	60.3		12
Tanwax-RM 10.5	16	172	103.7		3	41	88	58		3
Ohop-RM 0.2	47	163	70.1		14	36	436	81.4		24
Ohop-RM 6	16	70	29.2		26	24	77	43.2		27
Ohop-RM 9.9	12	77	32.4		20	13	2040	136.6		19
NH_3 (ug/L)										
Tanwax-RM 0.5	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Tanwax-RM 10.5	15	180	109		3	14	33	21.3		3
Ohop-RM 0.2	40	215	82.1		8	18	256	83.7		12
Ohop-RM 6	10	298	70.2		26	10	451	139.5		27
Ohop-RM 9.9	10	258	38		20	10	141	26.8		18
Nitrate (ug/L)										
Tanwax-RM 0.5	25	37	29.5		6	209	618	424.6		12
Tanwax-RM 10.5	28	181	104.3		3	26	496	228.3		3
Ohop-RM 0.2	152	343	244.6		14	282	1400	601.3		24
Ohop-RM 6	10	915	108.8		26	79	771	402.3		27
Ohop-RM 9.9	28	304	130		20	126	534	293.3		18

(1) Summer range calculated using July - September data.
(2) Winter range calculated using November - March data.
(3) Arithmetic mean calculated for all parameters, with the exception of Fecal Coliform which was calculated as the geometric mean value.

Water quality at the upper station appears to be greatly influenced by the lake outflow. Only one summer dissolved oxygen measurement and summer three temperature measurements were available for the upper station. The one summer dissolved oxygen measurement was extremely low (4.3), while temperature measurements were within the criteria. It is uncertain how representative these measurements are of normal or extreme conditions. The situation is, however, typical of the influence from a thermally stratified lake, and indicates that the outflow from the lake may be occurring from the mid level stratum. (High phosphorus concentrations measured in this system are also likely to be a result of the lake influence.) Dissolved oxygen concentrations recover between the upper and lower stations and easily meet the water quality standard at the lower station. Conversely, temperatures are higher at the lower station. According to this data subset, fecal coliform bacteria standards were met at both stations in summer, but were exceeded 8% of the time in winter at the lower station.

Tanwax Creek was one of the streams studied during a more comprehensive water quality investigation in the Lower Nisqually (Whiley et al, 1994). Tanwax was observed to exhibit a wide variation in flow, as well as elevated turbidity, TSS, fecal coliform and total phosphorus levels. In that study, fecal coliform levels were determined to exceed the State water quality standard, with more than 10% of the samples exceeding 200. Concentrations were found to be problematic in the dry season. No sources were identified for the elevated pollutant levels, however, it was noted that problems were related to the dry weather season and were likely a reflection of the very low flows measured at that time.

Ohop Creek

Ohop Creek is the second largest tributary to the Nisqually below La Grande Dam. It drains 44 square miles and is confluent to the Nisqually at RM 37.3. Lynch Creek and Twenty-five Mile Creek are the main tributaries and discharge to Ohop at RM 6.2 and 9.9, respectively. Both of these major tributaries have headwaters within the rain-on-snow zone, and are prone to sudden changes in discharge, although this is not as much the case for Twenty-five Mile since only a small area lies within this zone (Whiley et al., 1994). Lynch Creek also extends into the snow dominated zone. Ohop Lake, lies between RM 6.2 and 9.9 on Ohop Creek. It is the largest natural lake in the Nisqually Basin with a surface area of 235 acres.

Water quality data is available for three stations on this stream, located at RM 0.2, 6, and 9.9 (Table 4-6). The station at RM 6.0 is downstream of the lake and the inflow from Lynch Creek. The station at RM 9.9 is upstream of Ohop Lake but downstream of the inflow from Twentyfive Mile. The database provided by the Nisqually Indian Tribe provides a very intensive data record between 1995 and 1997, and monthly measurements in 1991 and 1992.

Dissolved oxygen levels at RM 9.9 meet the state criteria. The temperature criteria, however, is exceeded 8% of the time. The highest temperature recorded at this station is 19.4 degrees C.

Dissolved oxygen concentrations and temperatures at RM 6.0 do not meet water quality standards during the summer. This may be evidence of the influence from the lake. Maximum stream temperatures and minimum dissolved oxygen levels recorded at this site are both within the typical lethal range for fish.

Dissolved oxygen concentrations and temperature levels improve downstream of RM 6.0. However, both dissolved oxygen criteria and temperature criteria are violated frequently at RM 0.2. Minimum dissolved oxygen at the lower station is 6.3 and maximum temperature is 21.4 degrees C. The combination has the potential for significant adverse effects on fish populations.

The Ohop system has the highest bacteria concentrations measured in the lower basin. Mean late summer fecal bacteria concentrations are high at all three stations in this stream and exceed the water quality standard. The standard is also exceeded at RM 0.2 during the winter. A similar result was observed during a study in the early 90s (Whiley et al., 1994), when Ohop Creek was observed to have the highest median fecal coliform levels of all six streams studied in the lower Nisqually. This was true for both wet and dry season concentrations, although the dry season samples exhibited much higher concentrations.

During this same study of tributaries to the Lower Nisqually (Whiley et al., 1994), Ohop Creek was determined to have the highest median turbidity and TSS levels of the six streams studied. Sources of TSS and turbidity were found to differ by season. During the dry season, the source for the turbidity and TSS was determined to lie between RM 6.2 and 0.2 and was attributed to bank erosion associated with agricultural activities in this stream segment. During the wet season, Lynch Creek appeared to be the greatest source for TSS, while turbidity continued to be originating from lower in the basin. One of the concluding statements in this study was; “The Ohop Creek basin is complex and exhibits substantial water quality problems.” Further investigation into pollutant sources was recommended.

A more detailed investigation of the Ohop drainage was done in subsequent years (Whiley & Walter, 1997). Five stations on the Ohop and one station each in the lower reach of Lynch and Twenty-five Mile Creeks were studied. Again, water temperatures were found to be chronically elevated, exceeding the state standard for 70 days during 1993, and it was attributed to the lakes’ influence. Lynch and Twenty-five Mile were observed to have a cooling affect.

A sediment load and yield analysis was also performed during this study, and is summarized in Table 4-7. The table contains an average of results from 1994 and 1995. Although the load and yield data were widely different between the years, there was good consistency between the percent of the annual load in each year at each station, thus the averages are adequate for comparison purposes. (Unfortunately, there is a discrepancy in the sediment yield results between data reported in the text and that shown in tables, so that information has not been included in the table.) As summarized in the table, the greatest sediment load comes from the lower river (below RM 6.0), especially between this station and RM 3.3. According to the report, Lynch and Twenty-five mile Creeks exhibited relatively low sediment yields when compared to forested basins in the Mashel watershed. Thus, it was concluded that the source of elevated loads in the lower valley of the Ohop was associated with agricultural practices and streambank erosion.

Table 4-7. Average measured sediment loads in 1994 and 1995 in the Ohop Subbasin. Revised from Whiley & Walter, 1997.

	Annual Sediment Load	Percent of annual Load to RM 0.1
Upper Ohop (RM 9.9)	58	14%
Ohop (RM 6.0)	178	41.5%
Ohop (RM 3.3)	355	84.5%
Ohop (RM 0.1)	433	100%
Lynch Creek	97	21.5%
Twenty-Five Mile	54	12.5%

Kreger Creek

No comparable data sets were available for this subbasin, thus no water quality assessment is provided.

Mashel Subbasin

The Mashel Subbasin drains an area of 89.2 square miles in southeastern Pierce County. The three major tributaries to the Mashel are Busy Wild Creek and Beaver Creek in the upper reaches and the Little Mashel River in the lower reach. Since the subbasin reaches into the higher elevations on the flanks of Mount Rainier, its headwaters lies within both snow dominated and rain-on-snow zones. This means that it can experience sudden changes in discharge during winter warming periods.

The Mashel River is confluent with the Nisqually River at RM 39.6. It represents the largest contribution to the Nisqually within the study area (i.e. below LaGrande Dam). The average annual discharge of the subbasin is 254 cfs and it contributes 14% of the mean annual flow to the Nisqually. (Average annual discharge was calculated using stream flow data from representative USGS stream gages and adjusting these values to the area of the subbasin. Please refer to Chapter 5.1 for a discussion of which gages were used to represent each subbasin.)

Most of the Mashel is forested with second growth timber; forestry is the primary land use. Above RM 6.0, the subbasin is entirely forested. The Town of Eatonville is located near RM 5.5. Drinking water is withdrawn from the Mashel just downstream of Eatonville, near RM 5.7. Secondarily treated wastewater from Eatonville is discharged near RM 5.2. Some agricultural land is located near Eatonville and the Little Mashel River, which discharges to the mainstem just upstream of Eatonville.

Table 4-8 contains a summary of data provided by the Nisqually Indian Tribe, from four stations on the Mashel River. At the uppermost station (RM 14.5) and at RM 3.2, samples have been collected on a fairly regular basis between 1993 and 1996, while at RM 6.0 and RM 0.2 data extends from 1991 through 1998. Additional studies of the Mashel were done in 1991-1993 (Whiley et al., 1994) and in 1993-1994 (Whiley & Walter, 1997). These reports summarize extensive investigations including excellent discussions of seasonal trends and trends between stations or stream segments. These reports have been extensively summarized in this assessment.

As indicated in the table, even the minimum dissolved oxygen concentrations measured were above the Water Quality Standard. These results also held for the more intensive studies of the Mashel River (Whiley et al., 1994 and Whiley & Walters, 1997).

Temperature is exceeded at the lowermost station (RM 0.2) during the late summer critical period. Interestingly, temperatures also exceed standards at RM 6.0, and appear to be higher than at the next downstream station. A more detailed assessment of temperature in the Mashel was provided in the 1993-94 study (Whiley and Walter, 1997). The upper reaches of the Mashel (RM 7.8 and above) and Busy Wild and Beaver Creek exhibited relatively cool temperatures, although the temperature apparently exceeded 18°C in the upper reaches of the mainstem on some occasions. From RM 5.2 to the mouth (RM 0.6), temperature was elevated. In 1993, a relatively normal year in terms of flows and air temperatures (Whiley and Walter, 1997), there were three different occasions between the beginning of August and the middle of September when temperatures remained above 18°C for 3 to 8 day periods. In 1994, an unusually dry and warm year (Whiley and Walter, 1997), temperatures at RM 5.2 exceeded 18°C almost daily from early July to the beginning of September. Some cooling occurs in the mainstem between RM 5.2 and RM 0.6, due to the influence of the much cooler Little Mashel River and the increased shading that exists in the lower river.

Table 4-8. Mashel Subbasin, Water Quality Summary. (Data Source: Nisqually Indian Tribe Water Quality Program database.)

Parameter/Location	Summer Range (1)					Winter Range (2)				
	min	max	mean (3)	% exceedance	N	min	max	mean (3)	% exceedance	N
DO (mg/L)										
Mashel-RM 0.2	9	12.6	10.2	0%	10	10.3	14.5	12.4	0%	19
Mashel-RM 3.2	9.5	11	10.3	0%	5	11.3	14.5	12.9	0%	7
Mashel-RM 6	9.3	12.2	10.3	0%	10	10.3	15	12.6	0%	12
Mashel-RM 14.5	10.1	12.4	10.9	0%	6	12.1	14	13.1	0%	8
Temp (C)										
Mashel-RM 0.2	12	22.1	16.4	30%	13	0.6	10	5.6	0%	22
Mashel-RM 3.2	9.7	17.8	14	0%	5	2.2	7.3	5.2	0%	8
Mashel-RM 6	8.3	20	15.4	18%	11	2.4	8.5	5.5	0%	14
Mashel-RM 14.5	6.4	15.3	11.4	0%	6	1.7	6.7	4.4	0%	8
Fecal Coliform (MPN/100ml)										
Mashel-RM 0.2	25	685	68.9	8%	12	5	50	17.8	0%	17
Mashel-RM 3.2	18	580	56.5	14%	7	5	370	31.2	9%	11
Mashel-RM 6	5	135	30.7	0%	11	5	100	9.5	0%	15
Mashel-RM 14.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Turbidity (NTU)										
Mashel-RM 0.2	0.6	5.7	1.9		14	0.9	900	70.4		33
Mashel-RM 3.2	0.8	2.9	1.4		5	1.5	318	31.1		24
Mashel-RM 6	0.2	1.3	0.7		10	0.4	280.2	25.5		24
Mashel-RM 14.5	0.3	1.1	0.8		6	0.5	297.6	25.8		20
TSS (mg/L)										
Mashel-RM 0.2	0.3	5.7	1.7		16	0.1	2882.1	175.5		30
Mashel-RM 3.2	0.6	6.3	1.9		5	0.6	757.8	64.4		24
Mashel-RM 6	0.5	1.6	0.6		11	0.5	739	56.2		24
Mashel-RM 14.5	0.5	2.4	0.9		6	0.5	752.7	56.6		21
TP (ug/L)										
Mashel-RM 0.2	12	61	34.4		11	13	2440	276.9		16
Mashel-RM 3.2	22	317	131.7		3	11	161	43.6		9
Mashel-RM 6	3	23	12		8	9	149	35.2		12
Mashel-RM 14.5	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
NH_3 (ug/L)										
Mashel-RM 0.2	13	38	29.4		5	25	30	28		3
Mashel-RM 3.2	16	31	24.7		3	13	30	22		5
Mashel-RM 6	10	40	18.9		8	10	25	13.1		11
Mashel-RM 14.5	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Nitrate (ug/L)										
Mashel-RM 0.2	47	304	135.4		11	206	628	430.8		16
Mashel-RM 3.2	75	103	92		3	364	857	496.1		9
Mashel-RM 6	12	46	29.8		8	126	520	297.6		12
Mashel-RM 14.5	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a

(1) Summer range calculated using July - September data.
(2) Winter range calculated using November - March data.
(3) Arithmetic mean calculated for all parameters, with the exception of Fecal Coliform which was calculated as the geometric mean value.

Fecal bacteria concentrations exceed water quality standards at RM 3.2 during the late summer period, but meet the criteria at all three stations during winter. (No samples were taken at RM 14.5).

The turbidity standard also appears to be exceeded in the winter at the lowermost stations (RM 0.2). The turbidity at the upstream stations is fairly consistent, with mean values ranging from 25 to 31 NTUs. Assuming this represents the background condition, the mean value of 70.4 is well above the allowed increase of five NTUs. Clearly, a turbidity source exists below RM 3.2.

A comprehensive analysis of TSS loads and yields was done as part of an extensive two-year monitoring effort (Whiley & Walter 1997). The majority of the sediment load (88 to 94% of the annual load) was found to occur during the rising limb of the storm hydrograph. Only 2% of the annual load was transported during periods of steady flow (i.e. non storm event related).

A summary of the results from the loading analysis performed by Whiley et al. (1994) is provided in Table 4-9. The largest loading sources were the Upper Mashel (17%), BusyWild Creek (22%) and the Middle Reach (38%). However, a slightly different pattern emerges when the load estimates are corrected for the amount of land mass contributing to them; that is, when pollutant yields are estimated. The middle reach continues to be the problem segment and contributes twice the yield of the next highest area. However, the Upper Mashel does not appear to be a problem segment in terms of yield, while the Lower Reach of the Mashel and Busy Wild share second place for highest yields.

Table 4-9. Average measured sediment loads (tonnes/yr) and yields (tones/km^2/yr) in 1994 and 1995 in the Mashel Subbasin. (Revised from Whiley and Walter, 1997.)

	Annual Sediment Load	Percent of annual Load to RM 3.2	Yield
Upper Mashel (above RM 14.5)	1016	17%	22.5
BusyWild Creek	1284	**22%**	32.5*
Beaver Creek	68.5	2%	3
Little Mashel	471	10%	8
Middle Reach (RM 6.0-14.5)	2361	38%	76*
RM 6.0 to 3.2 (excluding L. Mashel)		11% (approx.)	33.5*
*These systems exhibited a large response to high flows and highly variable yields.			

A wide variation was measured between the two study years (1994-1995). In 1994 a more typical flow year, the yields were consistently low and varied from 2 to 14 tonnes/km^2/yr. By far the highest yield came from the middle reach of the Mashel, while the Little Mashel and Beaver Creek had the lowest yields (3 and 2 tonnes/km^2/yr, respectively). In water year 1995, a high flow year, the yields ranged from 4 to 138 tonnes/km^2/yr. Again, the highest value was from the middle reach, and the lowest from Beaver and Little Mashel (4 and 13 tonnes/km^2/yr, respectively). Even with the large flow variation between years, the load and yield pattern held.

Mainstem Nisqually Subbasin

On the mainstem Nisqually, stations were selected with the most extensive data record, which were LaGrande (RM 39.7), McKenna (RM 21.8), and the Nisqually Refuge (RM 3.7). At the upper station, samples were collected consistently between 1991 and 1999. At the McKenna station, data was collected between 1996 and 1999, with an intensive winter study in 1998 through 1999. At the lower station (RM 3.7), samples were collected on a somewhat sporadic basis between 1992 and 1994, and more consistently from 1994 through 1999.

Table 4-10 summarizes water quality data for the three stations along the mainstem of the Nisqually (data provided by the Nisqually Indian Tribe). In terms of water quality standards, the mainstem appears to be in good condition. As shown, the minimum dissolved oxygen concentrations at all three stations were well above 8 mg/L, even during late summer. Temperatures were also very good with mean late summer values well below 18°C and a maximum temperature of 18.2 °C (a minor violation of the temperature criteria). The fecal bacteria picture is also good. There are occasions during the winter months when numbers are elevated.

The Nisqually River was evaluated as one of the contributing sources of fecal coliform bacteria to Nisqually Reach in a study in the mid 1990s. The Nisqually River was observed to have the lowest fecal coliform bacteria concentrations of all the sources and stations monitored (Whiley & Walter, 1996). These results are described in more detail in a following section on river impacts to the Nisqually Reach.

Table 4-10. Nisqually Mainstem, Water Quality Summary. (Data Source: Nisqually Indian Tribe Water Quality Program database.)

Parameter/Location	Summer Range (1)					Winter Range (2)				
	min	max	mean (3)	% exceedance	N	min	max	mean (3)	% exceedance	N
DO (mg/L)										
La Grande RM 39.7	10	12.6	10.9	0%	9	9.8	15.6	12.5	0%	16
McKenna RM 21.8	10	13.8	11.3	0%	6	10.8	14.2	12.8	0%	11
Refuge RM 3.7	9.4	12.6	10.6	0%	15	9	14.3	12	0%	28
Temp (C)										
La Grande RM 39.7	10.8	16.4	14	0%	11	4.2	9.8	6.2	0%	19
McKenna RM 21.8	14.6	16.6	15.3	0%	6	3.8	9.7	6	0%	13
Refuge RM 3.7	11.1	18.2	15.8	11%	18	3.9	13.3	6.8	0%	33
Fecal Coliform (MPN/100ml)										
La Grande RM 39.7	2	20	7.7	0%	9	4	20	8.2	0%	6
McKenna RM 21.8	5	40	19.1	0%	6	5	500	24.2	7%	14
Refuge RM 3.7	5	200	21.9	0%	20	5	220	19.3	4%	28
Turbidity (NTU)										
La Grande RM 39.7	2	78	17.7		13	5.3	147	32.9		31
McKenna RM 21.8	1.6	78.2	24.3		12	4	503.4	61.1		29
Refuge RM 3.7	1.7	80	13		19	2.6	725.2	42.7		52
TSS (mg/L)										
La Grande RM 39.7	0.4	39.7	8.6		12	0.5	137.1	30.1		29
McKenna RM 21.8	1.6	39.5	12.8		12	1.9	1486.6	158		29
Refuge RM 3.7	1.3	65.5	8.8		20	2.6	1197.6	92.2		47
TP (ug/L)										
La Grande RM 39.7	2	38	15.8		11	7	228	55.9		16
McKenna RM 21.8	4	35	17.3		6	21	1280	225.6		14
Refuge RM 3.7	5	35	18.3		14	16	1280	121		22
NH_3 (ug/L)										
La Grande RM 39.7	10	16	12		3	15	40	26.3		3
McKenna RM 21.8	n/a	n/a	n/a		n/a	n/a	n/a	n/a		n/a
Refuge RM 3.7	14	42	30.8		6	10	24	17.6		7
Nitrate (ug/L)										
La Grande RM 39.7	15	49	29.3		10	46	205	127.6		16
McKenna RM 21.8	36	106	66.7		6	163	478	297.4		14
Refuge RM 3.7	92	172	135.1		14	153	1400	406.7		22

(1) Summer range calculated using July - September data.
(2) Winter range calculated using November - March data.
(3) Arithmetic mean calculated for all parameters, with the exception of Fecal Coliform which was calculated as the geometric mean value.

A more comprehensive water quality analysis of the Nisqually mainstem is provided in a recent report (Whiley & Walter, 2000). Temperature, dissolved oxygen, pH conductivity, total phosphorus, nitrate+nitrite and total suspended solids were all evaluated. In terms of dissolved oxygen, the river was observed to follow the normal seasonal trends. Concentrations were always above the water quality standard. The lowest median dissolved oxygen concentrations were measured below LaGrande reservoir. They are a result of the low depth of withdrawal from the reservoir and the naturally lower oxygen concentrations that exist at lower depths in lakes and reservoirs.

River temperatures were also affected by the reservoir. Temperatures met the water quality standard. Temperatures peaked in September in the lower river; a month later than what occurred above the reservoirs. It was concluded that the reservoir operations has affected the historic temperature regime in the lower river in three ways; 1) reduced daily temperature variation, 2) reduced peak summer temperatures, 3) increased late summer and early fall water temperatures.

The lower Nisqually and Nisqually Reach are included on the 1998 303(d) list for fecal coliform bacteria exceedances. Nisqually, with McAllister Creek, has been included in Ecology's priority list for a TMDL for FY2002.

POLLUTANT SOURCE SUMMARY

Table 4-11 was largely excerpted from a summary provided in a previous report (Whiley et al., 1994) with some modifications to reflect this Assessment. Agricultural activities (identified as agriculture, small farms, and dairy/cattle) are implicated as probable sources of water quality problems on McAllister and the lower reach of Yelm, and in the lower Ohop valley. Forestry is implicated in Lynch Creek (Ohop) and the upper Mashel. Residential development is only implicated as a problem source in parts of the Ohop system. However, the withdrawal of drinking water from McAllister springs by the City of Olympia could be considered as a residential impact. It does not result in pollutant contribution problems, but may be contributing to flushing problems within that system. Problems in that system may also be related to the decay of peat along the stream and the tidal influence that limits flushing of the creek.

Review of the data suggests three areas where temperature and dissolved oxygen levels are at or approaching levels of critical concern for fish. These are Powell, upper Murray, and Ohop Creeks (particularly below the lake). In each of these cases, water quality is likely a reflection of the presence of lakes or wetlands above the sampling stations. The situations may therefore be natural. Lower Ohop Creek also has significant temperature and dissolved oxygen problems likely related to land use.

Table 4-11. Water Quality Concerns, Their Period of Occurrence, Location, and Probable Source by Subbasin. (Revised from Whiley et al., 1994)

Tributary	Water Quality Concern	Occurrence	Location	Probable Source
McAllister	Fecal coliform	Annual	All	Agriculture
	Dissolved Oxygen	Annual	All	Agriculture and Groundwater
Muck	$NO3^-$	Annual	Groundwater influence	Groundwater
Murray	Dissolved Oxygen	Annual	Upper Basin	Not determined
Yelm	$NO3^-$	Annual	Lower Reach	Groundwater
	Fecal Coliform	Annual	Lower Reach	Sm. Farm/Cattle
	NH_3-$NH4^+$	Annual	Lower Reach	Sm. Farm/Cattle
Toboton	None Identified			
Powell	Dissolved Oxygen	Annual	Below Wetland	Natural Condition
Lackamus	None Identified			
Tanwax	TSS/Turbidity	Wet Season	Not determined	Not determined
	TP	Wet Season	Not determined	Not determined
	Fecal coliform	Dry Season	Not determined	Not determined
Kreger	None Identified			
Ohop Creek	Fecal coliform	Wet Season Dry Season	Lower Valley Lower Valley	Dairy/Cattle Dairy/Cattle
	TSS/Turbidity	Wet Season Dry Season	Lynch Creek Lower Valley	Forestry Bank Erosion
	NH_3-$NH4^+$	Wet Season Dry Season	Ohop L./Lynch Lower Valley	Residential Dairy/Cattle
	TP	Wet Season Dry Season	Lynch Ck. Lower Valley	Forestry Dairy/Cattle
Mashel	Temperature	Dry Season	Upper Basin	Forestry/Natural
	TSS/turbidity	Wet Season	Upper Basin	Forestry

IMPACT OF THE NISQUALLY ON CONDITIONS IN NISQUALLY ESTUARY

Three sources of information were utilized in preparing this section of the water quality assessment. An investigation of fecal coliform sources done by the Nisqually tribe (Whiley and Walter, 1996), a comparison of pollutant loads and yields from major systems in the Puget Sound basin by the USGS (Embrey and Inkpen, 1998), and a hydrodynamic modeling project currently being performed by Ecology.

Fecal Coliform Bacteria

Due to the shellfish growing areas found in the Nisqually estuary, the bacteria issue is a serious concern for the Nisqually watershed. An examination of the relative importance of different sources of bacteria to the estuary was performed (Whiley and Walter, 1996). In this study, the sources examined and compared included the Nisqually River, McAllister Creek, Red Salmon Creek, and five shoreline drainages.

The Nisqually River is, of course, the single largest freshwater inflow to the estuary. It contributes approximately 100 times more inflow than the next largest source (i.e. McAllister Creek). However, the majority of this flow (83%) originates from above LaGrande Dam and serves to dilute impacts from the lower basin where the greatest potential for pollutant sources exists. Nisqually was found to have the lowest concentrations of bacteria of the stream study stations. There was a significant difference in bacteria levels between seasons, with lower concentrations measured during the wet season. Although fecal levels were found to increase during storm events, they did not exceed state standards. Thus, it was concluded that rain did not significantly affect fecal concentrations in the river. (It should be noted that the storm event sample set is fairly small and may affect these conclusions.) An important conclusion of the study was that no correlation was found between fecal conditions in the Nisqually estuary and concentrations in the Nisqually River. The contribution from McAllister was found to be much more critical, as will be described below.

Another interesting aspect of this study (Whiley and Walter, 1996) was a statistical comparison of Ecology's fecal bacteria monitoring results from a fairly long-term record (1978 to 1995) near the mouth of the river. It was found that for this period of record, bacteria levels decreased at a rate of 1.4% per year. This was accounted for by an estimated 8.2% decrease that occurred over the five-year period from 1982 to 1986. An increasing trend (4.6%) was indicated for the following five-year period. It was speculated that the differences may be due to decreased livestock populations during the mid 80s, and increased human population in the late 80s.

McAllister Creek was found to be the most significant contributor of fecal coliform bacteria to Nisqually estuary (Whiley and Walter, 1996). Bacteria concentrations were found to be chronically elevated even with continual tidal dilution throughout the mainstem. Although there was no significant difference between dry and wet season bacteria concentrations, concentrations were significantly correlated with storm events. Concentrations measured in McAllister Creek were also positively correlated with bacteria levels over the Hogum Bay shellfish beds. It was concluded that McAllister poses the largest continuous source of fecal coliform bacteria to the Nisqually estuary, especially during storm events.

Red Salmon Creek is about one-tenth the size of McAllister and therefore its potential for impact to water quality in the estuary is that much less. Flow tends to be fairly constant indicating a groundwater source. Fecal bacteria concentrations were chronically elevated in this stream. Bacteria concentrations were positively correlated with storm events; the highest median levels during storm events of all the stations monitored. There was also a relationship between the magnitude of rainfall and measured bacteria concentrations. (Note: Nitrates were also found to be elevated in this stream and attributed to evidence of impacts from septic systems and agriculture). Due to the small inflow amount, dilution with the Nisqually River water, and tidal mixing, Red Salmon is not believed to be a large contributor to reach bacteria problems. However, there are clearly bacteria sources within this creek that warrant investigation and control.

The beach stations monitored along the shore to the west of McAllister also had chronically elevated bacteria concentrations, with storm event values that exceeded the State standards. Most of these stations were associated with residential developments and were probably affected by septic system failures. However, the discharge from these areas is low and therefore the relative contribution to the Nisqually estuary is expected to be minor.

Pollutant Loads and Yields

The USGS (Embrey and Inkpen, 1998) studied historical nutrient data to evaluate transport of nutrients in the major rivers of the Puget Sound Basin. The Nisqually River was one of the basins included in the study. Generally, the smallest yields were from rivers on the Olympic Peninsula. These rivers generally yielded less than 1 ton per square mile per year of inorganic nitrogen and less than 0.1 ton of phosphorus. The largest yields (greater than 1 ton per square mile per year of inorganic nitrogen and greater than 0.1 ton of phosphorus) were from basins draining the east side of the Puget Sound Basin. Some of the study results are summarized in Table 4-12. As shown, the Nisqually exhibits comparatively low nutrient yields, with results just slightly higher than what was estimated for the lowest yield watershed studied (i.e. Dungeness).

Table 4-12. Pollutant Yields Measured in Selected Puget Sound River Basins. (Tons per square mile per year.)

River Basin	TP	IN
Nisqually	0.09	0.6
Deschutes	0.1	1.0
Dungeness	0.05	0.3
Puyallup	0.4	1.0
Green	0.2	1.2
Snohomish	0.2	1.8
Stilliguamish	0.4	2.0
Skagit	0.2	0.9
Nooksack	0.3	1.8
Average of these Basins	0.24	1.29
Highest in Study[1]	0.4	2.8
Lowest in Study[1]	0.05	0.3

[1]These were the highest and lowest values measured in a study of 22 river basins in the Puget Sound Basin.

Hydrodynamic and Water Quality Modeling

The Washington Department of Ecology is currently working on a large scale hydrodynamic and water quality modeling effort for South Puget Sound. Similar to the USGS study, the information developed can be used to compare pollutant loads between basins. Watershed flows and loads are summarized for six different regions (Chambers, Deschutes/Budd/Henderson, Northern, Nisqually, Puyallup, and Western) (Roberts and Pelletier, Unpublished Report). According to this model effort, the Nisqually Basin represents 27% of the land area and 32% of the discharge to South Puget Sound. This information is used in the following paragraph to assess the Nisqually's contributions to pollutant loading to South Puget Sound in a relative sense.

The Nisqually represents roughly 30% of the total landmass and inflow to Puget Sound. If the Nisqually area were inputting roughly 30% of the total pollutant loads to the sound, then the total inputs would be roughly average relative to other basins. Eleven different parameters were assessed in the USGS study, including three different forms of nitrogen, three forms of phosphorus, fecal coliform bacteria, total organic carbon, total suspended solids, and dissolved oxygen. The amount of pollutants input from the Nisqually area was less than 30% with the exception of dissolved oxygen (32%), total suspended solids (34%) organic nitrogen (37%), and total organic carbon (35%). Thus, none of the parameters were grossly out of balance with what would be expected for an average contribution across the Puget Sound area.

An evaluation of whether these inputs are high enough to have negative effects on the aquatic resources of Puget Sound cannot be reasonably made without knowing the loading capacity of the sound. Dissolved oxygen is not a conservative property. Levels tend to adjust rapidly to local conditions. The higher dissolved oxygen levels would be considered locally positive, but are unlikely to have any significant large-scale effect. The higher total suspended solids may be attributed to glacial influences. It is unknown why organic nitrogen and carbon are somewhat higher than average.

It should be noted that according to the authors these study results reflect a particularly wet year when discharge from the Nisqually was 35% higher than normal. It is not yet known whether these relationships (percent pollutant contributions) will change during a more normal precipitation year. However, they are consistent with the USGS study in indicating that the Nisqually is in good condition relative to other large basins in the area.

GROUNDWATER QUALITY

INTRODUCTION

The following is a summary of groundwater quality in Nisqually Basin (WRIA 11). Nitrate, chloride, and fecal coliform bacteria were selected for assessment because they are commonly found to be problems in groundwater, they have associated health impacts, and they may be directly related to human caused contamination.

A study by the U.S. Geological Survey (USGS) (Drost, et al., 1998) and a large Washington State Department of Health (WDOH) database were the main sources of information used to produce this assessment. Some of the data could be separated into subbasins of the Nisqually, but much of it could not without further investigation. Where subbasin information was available, it is provided and described in that form.

METHODS

The quality of groundwater in the Nisqually Basin was evaluated by reviewing existing studies, databases, and reports. The majority of the information presented is from two large data sets (USGS and WDOH). Additional information is described from a baseline study in Yelm by the Washington State Department of Ecology (Erickson, D. 1998).

The USGS study (Drost et al., 1998) focused on the Thurston County Ground Water Management Area (GWMA) a 439 square mile area located in northern Thurston County. Only a small portion of this area was in the Nisqually Basin. Most of the data used for this study was collected in 1988-1989. Information was available for over 1,320 wells and springs. However, water quality information was only available for 356 wells and 3 springs. Only 54 of these were within the Nisqually Basin (50 in the McAllister subbasin and 4 in the Yelm subbasin). Water samples were analyzed for nutrients, iron and manganese, fecal coliform and fecal streptococci bacteria, physical attributes, some trace elements, and other parameters. The majority of the samples were collected from domestic use wells.

The WDOH database contains information collected from 1992 through the present on over 600 wells located throughout the Nisqually Basin. (Note: each well may have data for more than one sampling date). The database contains information on 43 different water quality parameters. The WDOH database did not have information on fecal coliform bacteria; however, analysis was done on nitrate and chloride concentrations.

Ecology’s Yelm Groundwater Baseline Sampling study (Erickson, D. 1998) focused on a seven square mile area south of Yelm. Although some of these wells could have been included in the USGS report the majority were south of Yelm and outside the GWMA. Therefore, this study is useful for extending the USGS study results. The study included data from 23 private water-supply wells. Sampling occurred bimonthly for one year for nitrate+nitrite-N, chloride, total dissolved solids, ammonium and fecal coliform bacteria.

RESULTS

Nitrate

Elevated nitrate concentrations typically indicate contamination from septic leachate, animal wastes, or fertilizer applications. The state primary drinking water standard for nitrate is 10 mg/L. Concentrations above this limit can inhibit the oxygen-carrying capacity of blood and may cause methemoglobenemia (blue baby syndrome) in infants.

Nitrate concentrations were below the drinking water standard in all the samples taken for the USGS study (Table 4-13). Overall, 93% of the samples had concentrations below 5 mg/L. Two wells within the McAllister subbasin had nitrate concentrations close to the drinking water standards. These wells are located to the northwest of Yelm just outside the boundary of the Yelm subbasin and within the McAllister subbasin. Nitrate concentrations for these two wells were 8.3 mg/L and 9.9 mg/L. Septic tanks and nearby chicken ranches were suggested as possible sources. None of the wells tested within the Yelm subbasin had nitrate concentrations near the drinking water standards, although the two wells just described that had nitrate concentrations near the drinking water standard were located near the boundary of the two surface water subbasins.

Table 4-13. Summary of nitrate concentrations measured by USGS in 54 wells located within the Nisqually Basin. All concentrations are in mg/L. (Revised from Drost et al., 1998).

Subbasin	Total Wells	£1	>1-5	>5-10	>10	Range
McAllister	50	22	24	4	0	<0.1-9.9
Yelm	4	1	3	0	0	0.49-2.4

Nitrate data for Nisqually Basin included in the WDOH database included 1,646 entries, from 374 different well locations. As shown in Table 4-14, the vast majority (72%) of the samples had nitrate concentrations below 1 mg/L, with 99% of the samples below the drinking water standard. Of the 12 measurements that were above the drinking water standard, six were taken from one location (351st Street Well Association). The average for all the samples taken at this one location was 10.4 mg/L. The largest concentration of nitrate was measured at the Bunger Water System #2 well (50 mg/L). However, four of the 5 samples collected from the site had concentrations well below 10 mg/L.

Table 4-14. Summary of nitrate concentrations measured by WDOH in 374 wells in the Nisqually Basin.

Concentration Range (mg/L)	Occurrence (# of samples)
£ 1	1,188
>1-5	420
>5-10	26
>10	12

The more intensive Yelm area study (Erickson, D. 1998) had similar findings to both the USGS study and the DOH database analysis results. The mean concentration for nitrate in all the wells sampled was 3.2 mg/L. Only one well exceeded the drinking water standard (Erickson, D., 1998).

Meeting the drinking water standard does not imply that concentrations are not elevated or that no contamination is occurring. Concentrations in the 1-5 mg/L range may indicate that an impact is occurring and, in terms of surface water quality impacts, an input source within this range might be considered significant (for purposes of this report nitrate concentrations above 4 mg/L were considered elevated). More than 50% of the wells in both McAllister and Yelm subbasins had elevated concentrations according to the USGS results, and nearly 30% of the wells had elevated concentration in the WDOH data set.

Thurston County Department of Health has created a "hotspots" map from available data illustrating known problem sites within Thurston County. Within the Nisqually basin or close to the boundary of the basin there are five "hotspots" noted on this map (Table 15). Four areas are mapped because they have elevated nitrate concentrations. All four have nitrate levels exceeding 4 mg/L and two of these areas have a smaller "hotspot" area within them with concentrations exceeding 7 mg/L. These last two small areas are considered to be "highly elevated". The fifth "hotspot" was associated with pesticides and is described later in this chapter.

Table 15. Locations of hotspots identified by Thurston County Department of Health and the parameters of concern.

Hotspot Number	Subbasin	Location	Rough Size[1]	Parameter
1	Yelm	SE of the City of Yelm, running north to south	Roughly 1 mile wide and 1.5 to 2 mile long	Nitrates >4 ppm
2	Yelm	At the headwaters of Yelm Creek	Roughly 2 square miles	Nitrates > 4ppm 2 small areas within the larger one at >7 ppm
3	Yelm	North and northeast of Lawrence Lake; roughly 0.5 to 1 miles from lake, running NNW to SSE	About 1 miles wide and 4 miles long	Nitrates >4 ppm 1 small area within the larger one at >7 ppm
4	McAllister	Encompasses the north end of Long Lake and extending north of lake	Roughly 1 to 1.5 miles long	Nitrates > 4 ppm
5	McAllister	An area just SE of the Long Lake complex	Roughly 2 square miles	Nitrates > 4ppm

[1] *The areas on the hotspots map are rough approximations. Actual areas affected may not precisely correspond with the mapped locations.*

Chloride

Elevated chloride concentrations in groundwater can be an indicator of several things, saltwater intrusion, natural occurrence, or other contamination sources. Chloride is commonly used as an indicator of saltwater intrusion, especially in coastal areas where groundwater withdrawals have shifted the balance between fresh groundwater and salty groundwater along the coast. Naturally occurring areas of high chloride concentrations inland can be due to “connate” seawater (trapped seawater seeping from sedimentary rock that forms into springs and seeps). Connate seawater has been found in the Nisqually Basin, while saltwater intrusion is not considered to be a large concern at this time (Mead, B., Pers. Comm.). Chloride concentrations can also be associated with land use activities (i.e. landfill leachate and septic effluent). The State drinking water standard for chloride is 250 mg/L; this is a secondary standard.

Chloride results from the USGS study (Drost, et al., 1998) are summarized in Table 4-16. As shown, all 54 chloride measurements taken in the Nisqually Basin fell well below the drinking water standard. The range of concentrations measured was from 2.5 to 12 mg/L; 84% of the measurements fell below a concentration of 5 mg/L.

Table 4-16. Summary of chloride concentration measured by USGS in 54 wells located within the Nisqually Basin. All concentrations are in mg/L. (Revised from Drost et al., 1998).

Subbasin	**Total Wells**	**£3**	**3-5**	**5-50**	**>50**	**Range**
McAllister	50	9	33	8	0	2.5-12
Yelm	4	0	3	1	0	3.6-5.2

The WDOH database had chloride data for 227 different wells with 534 samples. As shown in Table 4-17, similar to the USGS results, the vast majority (84%) was below 5 mg/L. Approximately 69% of the samples in the 5-50 mg/L range had concentrations below 10 mg/L. Only one of the 534 measurements exceeded the 250 mg/L standard. This was at the Little Mashel Water System. Four measurements were included for this water system; the remaining three had chloride concentrations over 50 mg/L, but were below the drinking water standard. Similar results were reported in the Yelm area study (Erickson, D., 1998). Chloride concentrations ranged from 1.2 to 17.3 mg/L, with a mean of 4.9 mg/L.

Table 4-17. Summary of chloride concentrations measured by WDOH in 227 wells in the Nisqually Basin.

Concentration Range (mg/L)	**Occurrence (# of samples)**
£ 3	279
3-5	168
5-50	83
>50	4

Fecal Coliform Bacteria

Although fecal coliform bacteria are ubiquitous in the surface water environment, their presence in groundwater is indicative of contamination. Typical sources of contamination include septic leachate, wastewater discharges, pets and farm animals, and animal waste spreading practices. The drinking water standard for fecal coliform is 0 coliforms/100 ml. Of the 53 wells monitored in the McAllister and Yelm Creek subbasins, none had a concentration that exceeded the drinking water standard.

As stated previously, fecal coliform bacteria were not included in the WDOH database. No fecal coliform bacteria were detected in samples collected as part of the Yelm area study by the Washington Department of Ecology (Erickson, D., 1998).

OTHER ISSUES

The fifth "hotspot" on the Thurston County Department of Health's "hotspots" map that is located within or near the boundary of the Nisqually Basin (Table 4-15), is an area of pesticide contamination (EDB, DBCP and others). EDB, 1,2-DCP, and DBCP (pesticides used as a strawberry fumigant) were detected in drinking water in 1984 and 1989 near Lake St. Clair and Pattison Lake. More recent sampling by Thurston County occurred from 1998 to 2001. Those results indicated that contaminant plumes have not moved or spread northward (the direction of groundwater flow) and concentrations have decreased (Berg et. al., 2001). These pesticides have been banned from use and the Environmental Protection Agency now requires follow up testing every three years (Berg et. al., 2001).

In addition to the five large "hotspot" areas (nitrates and pesticide), the Thurston County "hotspots" map indicates the location of six landfill/dumps (five of which are closed). These include the 4 Hoops Septage Disposal (closed), the Yelm Dump (closed), the Rainier Dump (closed), the Yelm Highway Dump (closed), and the Olympia Municipal Dump. No contaminants of concern were specified on the map for these sites. One wood fabricator site was also listed as a site of concern. The concern regarded potential organic and inorganic contamination.

ADDITIONAL INFORMATION SOURCES

Additional sources of groundwater data and reports that were identified during this effort are summarized in the following paragraphs. These studies or reports may be beneficial to use in more detailed assessments.

The Thurston County Department of Health and cities of Lacey, Olympia, and Tumwater joined in 1995 to fund an ambient monitoring effort (Berg, S., Pers. Comm.). Monitoring has been occurring since then on 40 wells located throughout northern Thurston County, only a few are likely to be located in the Nisqually Basin. The wells were selected as a continuation of the USGS study (Drost et al., 1998), previously summarized. The majority of these wells are for residential use. The database contains information on water levels, which are measured on a quarterly basis, and nitrate, iron, and manganese concentrations, which are measured twice yearly. In addition to this database, the Thurston County Department of Health maintains a database for six wells south of Yelm to monitor poultry farm impacts on nitrate levels (Berg, S. Pers. Comm.). The database includes information on well depth, bottom elevation, pH, conductivity, temperature, dissolved oxygen, nitrate, iron, and manganese (generally sampled twice a year). The database contains information from 1986 through 2000. Thurston County Department of Health has performed sanitary surveys in the Nisqually area that can be used as another source of information.

The Tacoma-Pierce County Health Department has a database for Group A (large public well systems monitored by WDOH) and Group B (water systems with less than 15 connections, monitored by the Local Health Department) wells within Pierce County. Much of the data in this database is also included in the WDOH database previously described. The period of record is longer for the Tacoma-Pierce County Health Department database, since it includes data from the 1970s (Serl, K. Pers. Comm.).

There are also several private water purveyors in the Nisqually Basin. All of these purveyors should have water system plans and prepare yearly water quality reports for their customers (Clark, S. Pers. Comm.).

WAC 179-351-990 requires groundwater quality testing for all landfills and submittal of quarterly and annual reports. For example, the Land Recovery Incorporated Landfill (otherwise known as the 304th Street Landfill) was completed in 1999. Groundwater data collection began in 1987 (at the start of the EIS process). Since operation of the landfill began, quarterly groundwater quality data has been collected on 16 inorganic constituents, 47 organic constituents, 4 field parameters, 10 geochemical indicators, and 3 leachates as required by WAC 173-351-990 (Comstock, A. Pers. Comm.). Although the testing is done in a localized area near the landfill, data sets like this may provide additional groundwater data specific to individual subbasins.

A water quality assessment of surface and groundwater was done as part of the Phase I Restoration Study for Clear Lake (Pierce County) in 1994. High phosphorus concentrations were measured in the groundwater at depths below 200 feet. The extent to which this may occur in other parts of the basin is not known; phosphorus was not one of the parameters selected for this assessment.

GROUNDWATER QUALITY SUMMARY

At the time of the USGS study, contamination of groundwater in Thurston County by commercial and industrial activities was minimal. Most of the water quality problems found in the study area were attributable to natural conditions. Iron and manganese were the most widespread. Naturally occurring iron concentrations can be as high as 21,000 micrograms/L and manganese as high as 3,400 micrograms/L (Drost et al., 1998). Although these can compromise aesthetic qualities of water, they are not a health risk. Connate seawater was also located in several isolated locations within the basin.

In terms of meeting drinking water standards, groundwater quality appears to be good throughout the Nisqually Basin. There are no known subbasin level problems and only a few known "hotspots". However, meeting the drinking water standard does not mean that concentrations of these constituents are not elevated. Four different areas in the Thurston County portion of the basin have been identified as having generally elevated (>4 mg/L) or highly elevated (>7 mg/L) nitrate concentrations. (Note: The majority of the well data used to identify "hotspots" in Thurston County was from single family wells and therefore were most likely located within the upper two aquifers (Mead, B., Pers. Comm.). The USGS study also notes that the largest nitrate concentrations are located in the shallowest aquifers. This is expected since the majority of nitrate sources are located at or near the surface (i.e. agriculture, septic systems, etc.).) Depending upon the volume of groundwater contributed, concentrations of nitrate above 3 to 5 mg/L would be considered significant when it is entering a surface water source. As described in the Surface Water Quality section, a number of the streams in the lower Nisqually basin have elevated nitrate concentrations that are associated with groundwater discharge.